INITIAL RESULTS OF A LOW-COST SAR: YINSAR

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Abstract— Synthetic Aperture Radar (SAR) is a useful tool for studying the earth's surface. YINSAR is a low-cost SAR, developed at BYU. Its purpose is to increase the use of SAR data in scientific and commercial applications. This paper describes the YINSAR instrument and shows some initial SAR images created with it. An estimation of the resolution of the images is made, and the future work to improve YINSAR is stated.

INTRODUCTION

In the last half of the 20th Century, Synthetic Aperture Radar (SAR) has been used to create high-resolution images of the earth's surface. SAR images are created by recording reflections of periodically transmitted microwave pulses. A computer then transforms the reflections into an image. Today there are several satellites, which use SAR to study the earth's oceans, wind patterns, and polar ice regions. Other SAR systems are flown in jet airplanes. Both the satellite and jet aircraft platform SAR systems have some characteristics that prohibit their use: high cost of construction and operation, and less control over when a given area of the earth is imaged. A small SAR with low operating costs could make research with SAR more available to the scientific community. To increase the cost-effectiveness and controllability of the study of the earth's surface through SAR, researchers at Brigham Young University have developed a low-cost SAR—YINSAR.

This paper reports on some initial SAR images created with YINSAR and estimates their resolution. The following section describes the YINSAR instrument and gives its current status. The next sections show YINSAR images and their resolutions and comments on the future development of YINSAR.

Figure 1: A Cessna Skymaster airplane serves as the YINSAR platform.

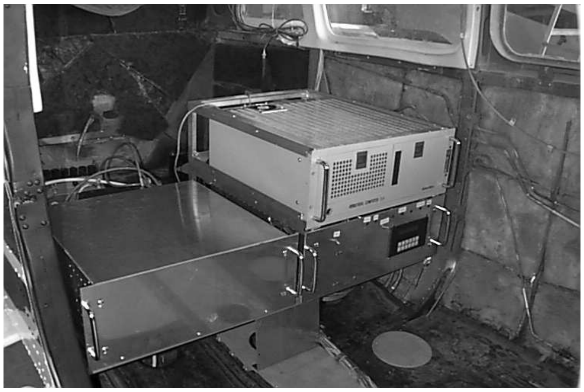

Figure 2: The three boxes that comprise YINSAR.

YINSAR DESCRIPTION

To reduce the cost of operation, a Cessna Skymaster serves as the YINSAR platform as shown in Fig. 1. YINSAR consists of three boxes. Each box is approximately the size of a desktop computer case, 17 × 19 × 7 in (43 × 48 × 18 cm). These boxes are shown in Fig. 2.

One box contains the CPUs, RAM and hard disk drives needed for controlling the SAR and storing the collected data. The program that controls YINSAR runs in DOS on two Intel x86 processors. This box also contains offthe-shelf A/D cards and a D/A card, which are necessary for discretizing the received signals and creating the range chirp.

The second box contains the RF subsystem, which consists of a microwave transmitter and a two channel receiver. The transmitter and receivers are composed of a commercial built microwave oscillator in addition to several commercial mixers and amplifiers. The transmitter has a peak output of 10W.

The third box houses the motion measuring equipment. An Inertial Navigation Unit (INU), kinematic GPS receivers, and differential GPS receivers record the position and dynamic motion of the aircraft. The motion data will be used to estimate the position of the YINSAR antennas so the radar images can be motion compensated.

All together YINSAR weighs just over 150 pounds. It is essentially the weight of an extra passenger in the airplane. At full power the instrument consumes approximately 600 W. Therefore, it does not require an expensive power supply, but is powered by the aircraft alternators through a DC to AC inverter. YINSAR connects to three slotted-waveguide antennas that are mounted to the bottom of the aircraft (1 transmit and 2 receive). The beamwidths of the antennas in the azimuth and range directions are 9 degrees and 40 degrees respectively.

A single person using a graphical interface program running on a laptop computer controls YINSAR during flight. The laptop user can adjust several parameters that change the performance of YINSAR. The user may also perform tests to verify the proper operation of YINSAR while in flight.

THEORETICAL PERFORMANCE

YINSAR operates at a center frequency of 9.9 GHz. The range chirp bandwidth is 100 MHz and both sidebands of the chirp and used to give an effective chirp bandwidth of 200 MHz. This results in an approximate range resolution for YINSAR of:

$$\delta_r \approx \frac{c}{2(BW)} \approx 0.75m$$

(c is the speed of light and BW is the effective chirp bandwidth).

Since YINSAR flies in a small aircraft, it can be flown at a low altitude ($<$ 3000 ft) allowing the use of smaller antennas while achieving good image SNR. The YINSAR antennas are 20 cm long. The theoretical resolution in azimuth is:

$$\delta_a \approx \frac{L_a}{2} \approx 0.1m$$

(L_a is the length of the antennas in the azimuth direction).

Figure 3: Target 1453A is in the center of the image.

INITIAL RESULTS

The data discussed in this section was collected on March 27, 2000. The radar was flown over the Cache Valley in northern Utah. Various types of terrain such as farming fields, rivers, and urban areas were imaged. The urban areas consisted of the cities of Logan, Hyrum, and Smithfield. The data was collected at a platform altitude of approximately 1000 ft. No motion compensation was performed on the images so they are not optimal.

During this flight, no photographs were taken or land measurements made of the objects flown over with YINSAR, so there are no known physical dimensions of the studied targets. Therefore, the targets do not give the exact resolution of YINSAR, but serve as an estimate. The targets used to analyze the resolution of YINSAR were chosen because they were bright (highly reflective) and relatively small compared to the surrounding areas of each SAR image.

The name for each image is based on the time of day the data was collected.

The first target 1453A comes from data processed to a range resolution of 1.2 m per pixel. It is shown in Fig.

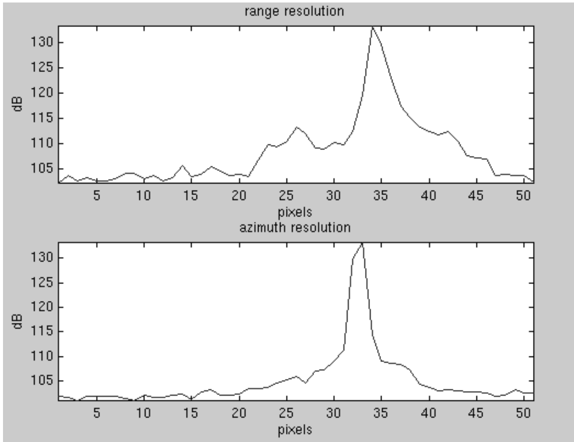

Figure 4: The range and azimuth response of target 1453A processed to a resolution of 1.2 m per pixel.

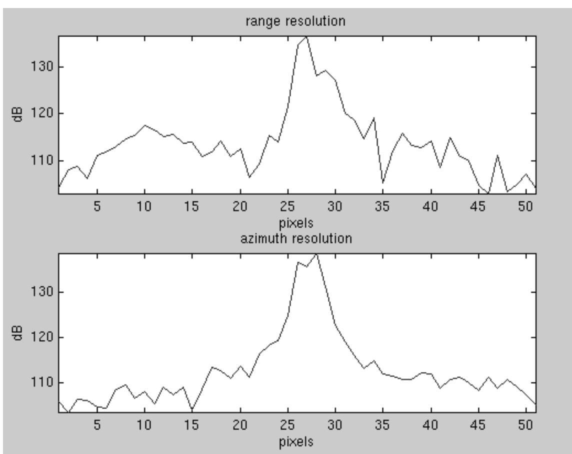

Figure 5: The range and azimuth response of target 1453A processed to a resolution of 0.6 m per pixel.

3. Notice the cross-shaped response of the target. It appears to saturate the receiver causing the sidelobes of the antennas to be visible.

In Fig. 4 is shown the range and azimuth response of target 1453A. The resolution is calculated by taking the 3 dB width of the target response. The range and azimuth 3 dB widths are 1.04 pixels (or 1.25 m) and 1.06 pixels (1.27 m), respectively. The resolution for target 1453A is near the processing limit of the SAR data.

To further analyze target 1453A, the data was processed to a resolution of 0.6 m per pixel. One can see the range and azimuth response in Fig. 5. The estimated range resolution is 1.44 pixels (or 0.867 m). This resolution is near the theoretical limit of the SAR. Still without knowing the exact physical size of the target, there is some uncertainty whether YINSAR can resolve targets of this size. In contrast, the azimuth resolution of the target decreased to 2.49 pixels (or 1.49 m). A possible explanation is that there are two targets near together in the azimuth coordinate. This is suggested by the dual peaks in the azimuth response in Fig 5.

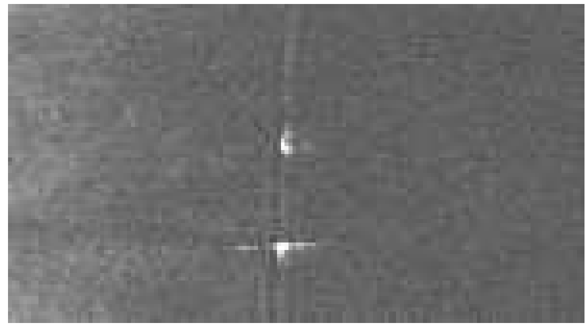

Figure 6: The target in the middle of the image is 1529A.

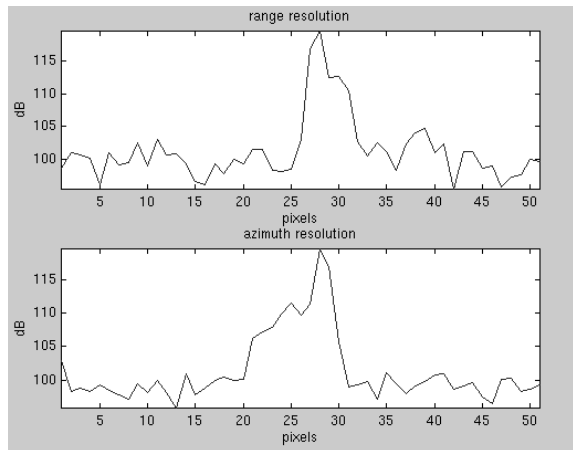

Figure 7: The range and azimuth response of target 1529A processed to a resolution of 0.6m per pixel.

A second target, 1529A, was also processed to a resolution of 0.6 m per pixel. It is shown in Fig 6. The range and azimuth response of the target are plotted in Fig 7. The estimated range resolution is 1.45 pixels (or 0.867 m), and the azimuth resolution is 1.40 pixels (or 0.838 m). Note that the range resolution for 1529A is the same as for 1453A, 0.867 m, when both targets are processed to 0.6 m per pixel. Perhaps this is coincidental, but it strongly suggests that the range resolution of

Figure 8: Image 1527A – This is farmland near Logan, UT.

YINSAR is 0.867 m. Again, since the physical size of the targets are unknown, there is some uncertainty in the previous conclusion. Further tests need to be conducted to remove the uncertainty in resolution.

The following images are YINSAR images of a non-urban and an urban environment.

Image 1527A (see Fig. 8) comes from farmland in Cache Valley, UT. It is processed to a resolution of 0.6 m per pixel. In the image one can see several trees and roads. The dark area is a river, and the fuzzy spots on the river are vegetation near the river surface. This image shows YINSAR has potential for use in archeology, land management, and land studies.

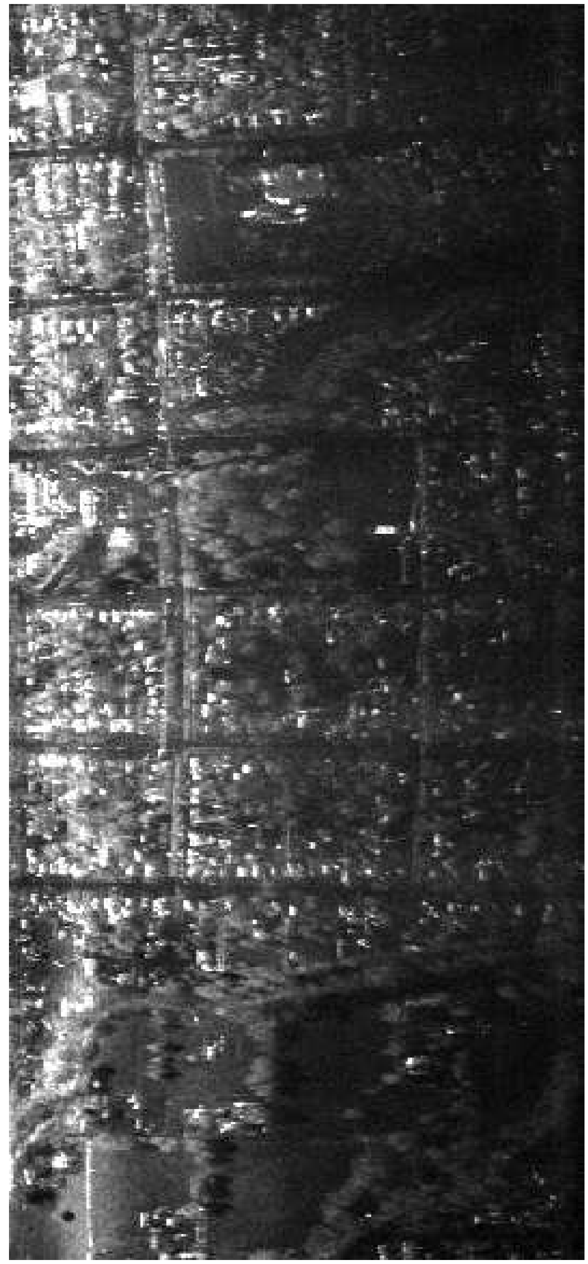

Figure 9: Image 1538A – This image is Logan, UT.

A part of Logan, UT is shown in image 1538A (see Fig. 9) with a resolution of 1.2 m per pixel. Manmade objects are especially visible. Buildings, streets, trees, and cars are readily seen. The streets are not straight because of the motion of the aircraft. This will be compensated for in the future. Microwave shadows from the trees can also be seen. The high resolution of YINSAR images lend themselves well to studying the earth's surface.

FUTURE WORK

Improvements to the YINSAR images will include interferometry and motion compensation. Compensating for motion will sharpen the YINSAR images. Topographical information will result through interferometry. Interferometry uses two receive channels. When these two channels are combined, a third axis (elevation) is added to the image. Thus one can produce images showing the change in elevation of the terrain. In addition, a video camera will be used when SAR data is collected to aid in the evaluation of the quality and resolution of YINSAR images.

SUMMARY

YINSAR is operational for single-channel SAR images. Early estimates for YINSAR image resolution are 0.867 m in range and less than that for azimuth. Despite lacking motion compensation, YINSAR images are full of detail. Future work will enhance the quality of YINSAR images.

ACKNOWLEDGEMENTS

This work was supported in part by a Rocky Mountain Space Grant Consortium Fellowship to RBL, a National Science Foundation Graduate Research Fellowship to DGT and by a NASA grant to DVA and DGL.

The maintenance and piloting of the Cessna Skymaster, which is critical to this work, is due to several flight instructors from Utah State and Duane Hill.